Environmental radiation survey in Kawamata-machi, Fukushima-ken: Measurement of radiocesium in soil and plants

Hirokuni YAMANISHI[1)]*, Masayo INAGAKI[1)], Genichiro WAKABAYASHI[1)], Shin-ya HOHARA[1)], Tetsuo ITOH[1)] and Michio FURUKAWA[2)]

1) Atomic Energy Research Institute, Kinki University, 3-4-1, Kowakae, Higashi-osaka, Osaka 5778502, Japan
2) Mayor of Kawamata-machi, 30, Gohyakuda, Kawamata-machi, Date, Fukushima 9601492, Japan
*yamanisi@kindai.ac.jp

The radiocesium (Cs) concentration in well water, soil, and plant samples collected from Kawamata-machi, Fukushima, was measured. No Cs (Cs-137) was found in the well water samples. More than 90% of the Cs-137 measured was found in the top 1 cm of soil. The Cs concentrations measured in agricultural products taken from the planned evacuation zone were lower than regulated levels.

Key Words: *Soil, wellwater, plant, radiocesium, measurement, planned evacuation zone*

1. Introduction

Radiocesium (Cs) was introduced into the Fukushima Prefecture when radioactive material was discharged during the accident at the Fukushima Daiichi Nuclear Power Plant (FDNPP)[1] in 2011. Kawamata-machi is located about 40 km northwest of the FDNPP. The Yamakiya district of Kawamata-Machi is part of the planned evacuation zone. Knowledge of the current environmental radiation levels in the Yamakiya distract is required for monitoring and redevelopment. The Atomic Energy Research Institute, Kinki University, in collaboration with Kawamata-machi officials, is currently investigating the environmental radiation levels in this region.[2,-4] The results show that at least 90% of the radioactive materials from the accident are found in the top 1 cm of soil.

In this study, well water, soil and plant samples were collected. The concentration of Cs in the samples was quantified using a germanium semiconductor detector. The isotope of Cs investigated here was Cs-137. Cesium-137 rather than Cs-134 was investigated for two reasons: (1) The half-life of Cs-134 is 2 years, which means the concentration can change significantly depending on the collection period. (2) The adsorption of Cs-134 and Cs-137 by the soil is the same. Therefore, only Cs-137 levels are required to understand the behavior of Cs in soil.

2. Experimental procedure

The samples were annealed at 105 °C until dry and their dry weight measured. The samples were then place into plastic containers (U8 container: diameter = 47 mm, height = 60 mm). Gamma ray measurements were performed using a hyperpure germanium semiconductor detector (HPGe) to measure the concentration of Cs in the samples. The detector was calibrated taking into account the standard volume radiation of the U8 container. The HPGe had a relative efficiency of 16.33% and the thickness of the lead cover surrounding the detector was 5 cm. The gamma studio software (SEIKO EG&G) was used to analyse gamma ray spectrum and to perform self-

Table 1. Radioactive Cs in well water as measured in July, 2011.

	(Bq/g)
37 sites	N.D.

Table 2. Cs-137 levels in a sunflower collected from Yamakiya elementary school in August, 2011

	(Bq/g)
Flower	0.535±0.013
Seeds	0.034±0.003
Leaves (upper)	0.478±0.015
Stalk（upper）	0.064±0.004
Leaves (lower)	2.624±0.050
Stalk（lower）	0.129±0.004
Roots	24.731±0.070
Soil 0-50mm	6.756±0.229

absorption compensation and sum peak compensation. The concentration levels of Cs-137 measured were adjusted taking the half-life of Cs-137 into account. This gave the concentration of Cs-137 at extraction. The radioactivity is expressed per dry weight.

3. Results and discussion

The numbers shown in the following tables are measured value and each error of measurement.

(1) Well water

The well water at 37 public facilities, including a public hall, was measured. Water was placed into a U8 container, without filtering, and measured for 80000 s (see results in Table 1). The well water, at all sites, had radiation levels of less than 1 Bq/kg, which is the minimum level that can be detected.

(2) Sunflowers

The levels of Cs-137 in sunflowers grown in the Yamakiya district was expected to have increased after the accident due to uptake of Cs from the soil. A sunflower was taken from the Yamakiya elementary school in August 2011. The concentration of Cs-137 was measured for each part of the plant. The results are given in Table 2. The level of Cs-137 is 610 Bq for one sunflower weighing 420g with 93% of the Cs being located in the roots of the plant. It is thought that Cs found in the roots comes from particles of soil contained within the root system.

Table 3-1. Cs-137 in levels in vegetables collected in June to August 2011.

			(Bq/g)
Higashi-fukuzawa (August 2011)			
	Carrot		0.0062±0.0005
		Peel	0.0085±0.0013
	Soil		1.2574±0.0444
Ojima (June 2011)			
	Potato		0.0106±0.0011
		Peel	0.0244±0.0023
	Soil		0.7880±0.0385
Haneda (June 2011)			
	Onion		0.0011±0.0003
	Soil		0.9484±0.0392
Kotsunagi (July 2011)			
	Onion		0.0009±0.0002
	Soil		0.1113±0.0137
Kotsunagi (August 2011)			
	Potato		0.0016±0.0001
		Peel	0.0027±0.0006
	Soil		0.4344±0.0028

Table 3-2. K-40 in levels in vegetables collected in June to August 2011.

			(Bq/g)
Higashi-fukuzawa (August 2011)			
	Carrot		0.101 ±0.007
		Peel	
Ojima (June 2011)			
	Potato		0.146 ±0.017
		Peel	0.115 ±0.023
Haneda (June 2011)			
	Onion		0.053 ±0.008
Kotsunagi (July 2011)			
	Onion		0.030 ±0.006
Kotsunagi (August 2011)			
	Potato		0.122 ± 0.003
		Peel	0.143 ± 0.015

(3) Vegetables

Carrots and potatoes were collected from Yamakiya, peeled and measured. The concentration in the peel was also measured. The concentration of Cs-137 and K-40 are given in Table 3-1 and Table 3-2, respectivery. The concentration of Cs-137 is higher in the peel than in the other parts of the vegetable, but is much less than 100 Bq /kg. The transfer factor for the potato is high at 0.013.

(4) Leaf litter

Leaf litter from the Japanese cherry, sakura, was collected from the garden at the Kawamata kindergarten in August 2011. In order to remove any adhering soil particles the surface of the leaves was gently washed using cold water. Measurements were carried out after the

Table 4. Cs-137 levels in the leaf litter collected from the Japanese cherry at Kawamata kindergarten in August 2011.

			(Bq/g)
Leaf litter			0.5967±0.0085
Soil	0-10mm	depth	5.0079±0.0755
	10-20mm		8.4238±0.0985
Soil	0-10mm	depth	0.3274±0.0191
	10-20mm		0.0057±0.0015

Table 5. Cs-137 levels in the leaf litter collected from the forest neighboring Yamakiya elementary school in October 2011.

		(Bq/g)
Leaf litter: Dry field		3.04±0.06
Leaf litter: End of forest		129.47±0.41
Leaf litter: Forest		265.52±0.58
Rib: End of forest		94.75±0.31
Rib: Forest		49.98±0.21
Soil	0-5mm	48.91±0.36
	5-10mm	5.17±0.12
	10-35mm	0.41±0.01
	35-50mm	0.03±0.00

Table 6. Cs-137 levels in rice plants from Iizaka in October 2011.

	(Bq/g)
Brown rice	0.0039±0.0004
Straw(upper)	0.0283±0.0050
Straw(lower)	0.0503±0.0119
Soil	1.2236±0.0268

Table 7. Cs-137 levels in grasses taken from Yamakiya elementary school in May 2012.

		(Bq/g)
Mugwort		2.40±0.03
Pine needles		0.61±0.02
Dandelion		3.62±0.04
Clover		1.60±0.02
Soil	0-5mm	32.51±0.11
	5-10mm	16.01±0.07
	10-35mm	2.11±0.02
	35-50mm	0.19±0.01

Table 8. Cs-137 levels in dust at Kawamata-minami elementary school in July 2011

	(mBq/m^3)
Dust	3.08±0.473

leaves were dried at 105 °C. The results are given in Table 4. Cs-137 was most likely absorbed by the trees via their roots, since at the time of the accident on March 15, 2011 the branches did not have any leaves or flowers on them.

Leaf litter was also collected from the forest contiguous to the Yamakiya elementary school in October 2011. The results are given in Table 5. The collected leaf litter contained mainly leaves from broadleaf trees. Cs-137 found in the leaf litter has three sources: (1) Cs absorbed by the surfaces of the leaves directly, (2) Cs absorbed by the roots from the soil and (3) Cs absorbed by soil particles found attached to the surface of the leaf litter.

(5) Rice plants

The Cs-137 levels measured in rice plants at the time of harvest are given in Table 6. The transfer factor from the soil to the brown rice is small at 0.003.

(6) Grasses and pine needles

Cs-137 levels were measured in weeds taken from managed grasses at Yamakiya elementary school. The results are given in Table 7. Radioactive Cs has a high concentration at the soil surface where the grasses and weeds were found growing. A high concentration of Cs-137 is also seen in Mugwort and Dandelions. Mugwort and Dandelions are short in height and have shallow roots. The high levels of Cs-137 may therefore come from absorption of Cs in the surface layers of the soil.

(7) Dust

Air-borne dust was collected along the road in front of Kawamata-minami elementary school. The dust was collected at a flow rate of 400 L/min for 1 h at a height of 1 m above the road's surface. After collection, the filter paper was measured by HPGe. The result is given in Table 8. For a breathing volume of 22 m^3/d, the amount of Cs-137 breathed in over the course of one day is 0.07 Bq. This level will change depending on the amount of time spent outdoors, the weather conditions and the wind speeds. However, 0.07 Bq is considered to be low enough not to cause any adverse health effects.

4. Conclusions

The transfer of radioactive Cs from the accident at Fukushima to the environmental surroundings was obtained by measuring Cs-137 concentrations in soil and plant samples. In undisturbed areas, the concentration is highest at the soil surface where at least 90% of the Cs recorded is found in the top 1 cm of soil. The levels of Cs-137 found in the plants was seen to depend on the concentration in the surrounding soil. In comparison with other regions, the concentration of radioactive Cs was high in the Yamakiya district, which is in the planned evacuation zone. The concentration was highest in the leaf litter taken from the forest in the Yamakiya district. Periodic monitoring of radioactive Cs levels in grasses and weeds should be carried out where waste plant material is generated by weeding or decontamination.

References

1） M. Chino, H. Nakayama, H. Nagai, H. Terada, G. Katata, and H. Yamazawa “Preliminary estimation of release amount of 131I and 137Cs accidentally discharged from the Fukushima Daiichi Nuclear Power Plant into the atmosphere” J. Nucl. Sci. Tech., 48, 1129−1134 (2011).

2） T. Itoh *et al*., “Survey of Environmental radiation in Kawamata-machi, Fukushima-ken,” Annual report of Atomic Energy Research Institute, Kinki University 48, 3-9 (2011), [in Japanese].

3） H. Yamanishi *et al*., “Survey of environmental radiation in Kawamata-machi, Fukushima-ken―Radioactive cesium concentration in soil,” Radioisotopes, (under review), [in Japanese].

4） H. Yamanishi et. al., “Radioactive cesium concentration in topsoil for each grain size,” Jpn. J. Health Phys.i (under review), [in Japanese].